

The Tidal Régime of the River Mersey, as Affected by the Recent Dredgings at the Bar in Liverpool Bay.

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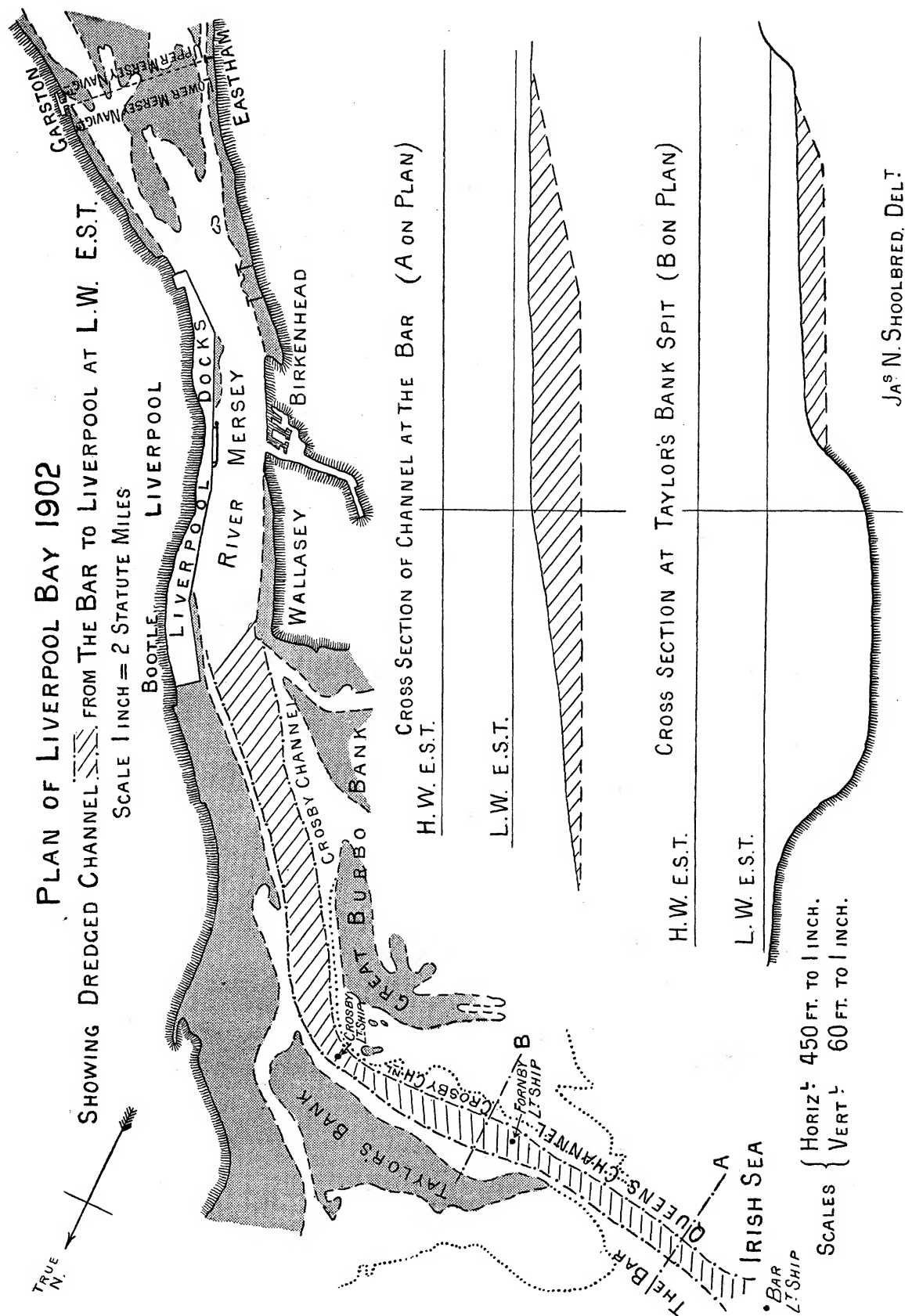
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Liverpool, the premier port of the world after our metropolis, with the annual total of in-and-out tonnage, in 1904, of 32 millions of tons, had suffered, in the approach thereto, up to about 15 years ago, from a sand-bar, situate at the outer or seaward entrance into Liverpool Bay, which afforded a depth of water over it, at low water of equinoctial springs, of only ten feet. When it is borne in mind that some of the large Atlantic liners have a draft of close upon 30 feet, it is easy to conceive the amount of inconvenience, chiefly by loss of time in enforced waiting outside the Bar, which this caused—a period of waiting, which affected more or less, according to their individual tonnage, all vessels visiting the port.

Attempts were made as far back as 1838 by the then Marine Surveyor of the Port of Liverpool, Lieutenant (afterwards Admiral Sir) H. T. M. Denham, to diminish the height of the Bar, by first harrowing the sand and then removing the loosened material by means of bucket-dredgers. After some years, however, it was found advisable to abandon these operations, since the effect thereof upon the Bar was so slight that a single storm from the Irish Channel often more than counteracted any deepening at the Bar, which had been effected by months of dredging. It was not, however, till shortly before 1890, that the late Mr. G. F. Lyster, then Engineer to the Mersey Docks and Harbour Board, was able to resume the attempt to remove any material at the Bar, by calling to his aid the newly invented form of sand-pump dredger, which by means of exhaust suction displaced the material in a semi-liquid state with such rapidity as to cause very sensible progress to be made in the removal of the material.

These preliminary experiments having proved sufficiently successful, in 1890 the problem of the removal of the Bar was vigorously attacked. At the end of ten years the problem was practically solved, so far as the cause of delay to incoming vessels entering the Port of Liverpool was concerned, since a minimum depth at the Bar of 26 feet of water at low water of equinoctial spring tides had been secured, or a gain of 16 feet of water over the conditions which prevailed in 1890.

Dredgings, however, are still continued; not merely at the Bar itself, but



throughout the entrance channels right up to Liverpool, in the vicinity of the landing stage, so as to enable the largest Atlantic liners to make use, at any state of any tide throughout the year, of the entire length of this waterway, 16 miles, which at night is illuminated by gas-lit buoys.

The total of the dredging operations by which the above results have been arrived at between 1890 and the present time may be thus summarised :—

Dredgings, at the Bar, 35 million tons of sand; in the estuary channels 50 million tons; in the river itself 15 millions; making a total of 100 million tons. This has provided a channel at the Bar with a minimum width of 1500 feet and a depth throughout, at low water equinoctial spring tides, of 28 feet, from the Irish Sea right up to the Liverpool Landing Stage, thus forming a worthy approach to this most important port. (See the accompanying plan and cross sections of dredged channel in Liverpool Bay.)

The British Association for the Advancement of Science, which has for the last thirty years, or more, paid considerable attention, by means of committees and in other ways, to the tides in the Mersey and in the Irish Sea, and inclusive of the Harmonic Analysis of the resulting records, naturally desired to ascertain whether, and to what extent, the extra facilities afforded at the deepened Bar to the ingress and egress of the tidal current had in any way caused any alteration in the tidal curves—primarily at Liverpool, and also at other points throughout the tidal establishment of the river, that is, between the Bar and Warrington.

With this object, a Committee of the Engineering Section of the British Association was appointed at the recent Southport meeting, consisting of Lord Kelvin, F.R.S. (Chairman), and Professors Sir George Darwin, F.R.S., Osborne Reynolds, F.R.S., Hele-Shaw, F.R.S., and W. Cawthorne Unwin, F.R.S., together with the writer, as Secretary. That Committee presented their report at the succeeding meeting at Cambridge, in 1904. They reported that by means of a large number of documents, tidal-curve records, etc., which the Mersey Docks and Harbour Board had placed at their disposal, they had found, with the co-operation of Mr. Edward Roberts, of the Nautical Almanac Office, as to the Harmonic Analysis :—

(a) That in the principal factors in the Harmonic Analysis of the tidal-curves of 1902 at Liverpool itself there appeared to be no appreciable difference from the similar data which had been presented by Sir George Darwin, F.R.S., to the Royal Society in 1885, and in 1889.

(b) That a comparison of the tidal curves of the equinoctial springs and neaps of the vernal equinox, in 1893 and in 1903, at Liverpool and at six other points on the river showed that no material change had occurred during that interval, either in the range of the tide or in the form of the

curve; but that in the extreme upper reaches of the narrow fluvial portion near to Warrington the tidal stream set in earlier, and remained somewhat later during the ebb, in 1903 than in 1893.

The object of the present communication is to submit the comparative diagrams of the tidal curves, in 1893 and in 1903, at the seven localities above referred to, which cover the entire tidal establishment of the Mersey, and to do this, not merely at the vernal equinoctial spring tide, and at its corresponding equinoctial neap, as was done in the British Association Committee's Report, but to extend the comparison so as to show by means of the continuous tidal curve, which occurred in 1893, and also in that of 1903, during the whole fortnight of the vernal equinox, there have been prepared likewise similar continuous tidal curves for the fortnight of the autumnal equinox in both of the above years.

The result of this lengthened comparison of the tidal curves is that thereby may be seen the gradual progress, at each corresponding period, in the alteration in the times of high water and of low water, and also in the additional tidal water now introduced at certain periods into the upper reaches of the river. There is also brought out the relative value of the varying and progressive effects at the different points of the river. Diagrams (not here reproduced) indicate that, at the four points lowest down the river (see accompanying plan), viz., the Bar (Helbre Island), Liverpool (George's Pier), Eastham (entrance to the Manchester Ship Canal), and Garston Docks, on the opposite Lancashire shore (at all of which places the full range of all tides is felt), there is but little, if any, difference between the tidal curves of 1893 and of 1903, that is, before the dredging operations were actively commenced, and the date when the present increased depth of channel was attained.

A line drawn across the river from Garston to Eastham forms the imaginary division between the Lower and the Upper Mersey navigations. The former, with its total navigable length from the Bar of 20 miles, obtains therefore the full advantage for the Port of Liverpool of the complete range of all tides. This is a matter of the utmost importance, since of the 32 millions of the tonnage of the shipping in and out of the Mersey, in 1904, no less than 28 millions were confined to the Lower Mersey, while of the balance of 4 millions in the Upper Mersey, $3\frac{1}{4}$ millions went up the Ship Canal to Manchester, and the remainder to Widnes and to Ellesmere Port. All the larger steam and sailing vessels entering the Mersey, with but a few exceptions which go to Manchester by the Ship Canal, make the Port of Liverpool their destination.

From the connecting line between Eastham and Garston above referred to,

as dividing the Lower and the Upper Mersey Navigations, the bed of the River Mersey rises rapidly, through what is known as the Upper Estuary, to Runcorn Bridge, joining the towns of Widnes and Runcorn; throughout a distance of nearly 11 miles of the wide, sandy Upper Estuary there is an average rise of 18 inches per mile in the river bed. From Runcorn Bridge to Warrington, somewhat over nine miles, where the river partakes more of the character of an inland stream, the rise in the bed is not so steep, having an average gradient of but 12 inches per mile.

The effect of this steep rise in the river bed upon the tides, and particularly upon the range thereof, is very marked. Throughout the entire length of the Lower Mersey Navigation of 20 miles, the full range of each tide is available. This may be taken as 31 feet on equinoctial springs, and as 10 feet on equinoctial neaps; the high water of the former tide rises to 21 feet above the "Old Dock Sill" at Liverpool, and the latter reaches there to 10 feet above the same level. This "Old Dock Sill" datum-level has been in use, in this part of the Irish Sea, for the last 150 years at least, and the more recent, but more generally known, "Ordnance Datum" or "Mean Tide Level at Liverpool" is usually taken at 4·7 feet (4' 8") above the "Old Dock Sill."

At Widnes, however, the range on the same springs is reduced to 14' 6", and for the neaps to 9 feet; while at Warrington, those springs have barely 9 feet of range and at the neaps in 1893 it was practically nil. But in 1903 these weak tides are much more visible at Warrington, though their influence is distinctly felt at Fiddler's Ferry, five miles lower down the river.

The effect of the up-hill gradient upon the rising tide is further shown in the additional height to which the high waters reach in the upper portions of the river. Thus at Widnes the equinoctial springs and neaps respectively reach a level of 1 foot at springs, and of 3 feet at neaps, higher than at Liverpool; while at Warrington the corresponding levels are, on an average, higher by 3 feet at springs, and by 7 feet at neaps than at Liverpool.

The result, therefore, of the examination of the continuous curves, each extending over a fortnight, does but confirm the conclusions of the Committee of the British Association, based upon the curves of the equinoctial springs and neaps only, that but little, if any, changes occur in the tidal conditions which prevail in the "Lower Mersey," and which affect the Port of Liverpool itself, consequent upon the recent dredgings at the Bar; this lower portion of the river being by far the most important as far as the interests of navigation are concerned.

Respecting the upper reaches of the river, near to Warrington (where, however, the navigation is not of much importance), these fortnightly con-

tinuous tidal curves show that there now remains in the river, between the respective high waters, a considerable body of water, more than there used to be before the dredgings at the Bar took place—an advantage, no doubt, to the local navigation. This increase in the amount of water appears more clearly upon these fortnightly continuous curves in the interval between the equinoctial springs and neaps than at the times of maximum and minimum range respectively of the tides. It is not possible, however, to arrive at any definite statement of the correctness, generally, of this effect without a careful examination of all of these fortnightly periods, throughout the entire year, since during each of these periods the strength of the tidal force would vary from that of its immediate predecessor, or successor.

The following table may prove of interest in connection with the above remarks, and as confirming the statement as to the small amount of change which has taken place in the tides at Liverpool during the last 50 years:—

Comparison of Harmonic Analyses of Tidal Observations at Liverpool.
53° 24' Lat. N., 3° 0' Long. W.

	Mean of 1857—60.*	Mean of 1866—70.*	1902.†
Principal Solar Series—			
S ₁ { H	0·066	0·038	0·003
κ	62	83	97
S ₂ { H	3·240	3·101	3·188
κ	11	12	11·32
S ₄ { H	0·056	0·058	0·043
κ	316	313	307·4
Principal Lunar Series—			
M ₁ { H	0·020	0·039	0·032
κ	258	336	345·5
M ₂ { H	10·100	9·881	10·091
κ	326	327	326·45
M ₃ { H	0·124	0·097	0·111
κ	324	324	319·0
M ₄ { H	0·702	0·683	0·657
κ	222	223	224·2
M ₆ { H	0·211	0·184	0·180
κ	348	350	353·6
M ₈ { H	0·077	0·061	0·052
κ	271	285	248·6

* Communicated to the Royal Society, in 1885, by Sir G. H. Darwin, F.R.S. ('Roy. Soc. Proc.,' vol. 39, p. 135).

† Computed by Mr. Edward Roberts, F.R.A.S. (Nautical Almanac Office).

Of the constants κ and H, the angles " κ " are referred to the meridian of Greenwich, and denote the lag of the tide; the "H's" are in feet and decimals thereof, and indicate the semi-tidal range.

The mean tidal level for 1902 = 4·952 feet above "Old Dock Sill."